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Depth Perception Applied to Search and Target Acquisition

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1. SUMMARY

A search and target acquisition test was performed under an exchange scientist program with the TNO Human Factors Research Institute at Soesterberg, The Netherlands in September 1998. The test was performed at a military training base using several of the scientists from TNO wearing Dutch forest camouflage uniforms.

Sets of wide baseline stereo photos were obtained for targeted and non-targeted scenes at two sites. The targeted and non-targeted scene photos were taken on the same day within a few minutes of each other. The imagery obtained was taken with a 35 mm camera with a 200 mm lens for target ranges from 100 m to 1 km. A single field of view was used for all of the targeted and non-targeted scenes at each site. The photos were taken with color slide film and were digitized to 3K by 2K pixel resolution. These imagery data sets were used to perform search and target acquisition tests.

Preliminary analysis of single line of sight search and target acquisition observer tasks was performed for the same scenes with and without targets. Results of these observer tests are presented. Additionally, the scenes used in these tests were made into stereo pair images for observer display. There are several aspects to the display of wide baseline stereo images that must be taken into consideration for optimum depth perception for use in search and target acquisition. Rule of thumb guidelines for optimizing the depth perception of the contour of camouflaged targets versus terrain features have been derived.

Keywords: Search, target acquisition, depth perception, stereo vision, camouflage, clutter

2. INTRODUCTION

The rationale for performing this research was the results from the Distributed Interactive Systems Search & Target Acquisition Fidelity (DISSTAF) Test conducted at Fort Hunter-Liggett, CA in 1995. The visible data sets collected by the Dutch are currently being used to evaluate the camouflage, concealment, and deception (CCD) performance models for the NATO SCI-12 Working Group.[1] A group from the Army Research Laboratory collected wide baseline stereo imagery at the DISSTAF Test. The results of showing this stereo imagery to some of the observers used for the DISSTAF Test was that there are depth cues that can be used at multiple km ranges for search and target acquisition tasks.[2] These results coupled with applications of stereo vision for detecting camouflage need to be quantified for comparison with the single line of sight search and target acquisition methodology.[3] The problem of course is that there currently aren't any good models for handling clutter in imagery, even for single line of sight imagery analysis, especially when the targets are camouflaged. This deficiency was recently highlighted by James Ratches of the U. S. Night Vision at the SPIE AeroSense Symposium in an Invited Overview paper of Night Vision's efforts past, present, and future.[4] On the top of the list for future research efforts was clutter quantification.

To begin to address the issue of how to compare single line of sight search and target acquisition versus stereo vision, discussions were made between Wendell Watkins of US Army Research Laboratory (ARL) and Matthew Valeton of the Dutch Institute for Perception (TNO) at the SPIE AeroSense Symposium in Orlando, FL, USA in April 1998 for a joint research project under the exchange scientist program (APEX). APEX funding was obtained in the summer of 1998; and, a research project was conducted in September 1998 at the TNO Human Factors Research Institute, Soesterberg, The Netherlands.

2.1 Test Plan

Bearing in mind that there is no standard method for comparing single line of sight (monocular or bi-ocular) versus stereo vision for various search and target acquisition tasks, a test plan was drawn up for

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investigating how to quantify scene clutter for both single and stereo lines of sight. The objective was to collect and analyze a database of images at a suitable test site with suitable targets for the derivation of a clutter quantification algorithm. The simplest targets to use were humans with suitable attire to match the surroundings sufficiently that all of the targets were not obvious and sufficient clutter was present to assess target placement in different clutter regions. The imagery database also had to have several lines of sight for assessment of stereo vision for comparison with bi-ocular vision performance for the same task. The human inter-ocular separation for maximum unaided depth perception ranges is about 10mrad. Several multiples of this separation distance were utilized for assessing the performance of stereo versus bi-ocular vision for the same vision task. Of course there were several more pages of details in the test plan of how to set up this field experiment and how to analyze the results.

2.2 What Was Really Done

The first issue that had to be addressed was what cameras were available for collection of the stereo imagery database. Sufficient 35 mm cameras and 200 mm lenses were obtained to set up four stereo cameras. The targets used were humans wearing Dutch forest camouflage uniforms. The test was conducted over a two-day period at the Soesterberg artillery facility where two sites were used. The first had shorter ranges (110 m to 675 m) with sunny/partly cloudy conditions. The second had longer ranges (400 to 900 m) with cloudy/rainy conditions. The first site had four camera positions with 6 m separation, and the second had three camera positions with 10 m separation. The camouflaged human targets were arrayed in sets of four for each of six different target locations. Slide photos of designated target positions, targeted scenes, and non-targeted scenes were taken at each of two test sites. This resulted in an imagery database that has 24 targets for four stereo lines of sight for the first site and three stereo lines of sight for the second site. Because photos were taken with and without the targets present, the impact of target placement and background clutter levels can be analyzed.

3. FIELD EXPERIMENTS

3.1 Measurements

With 35 mm cameras a camouflaged human can only be detected in digitized photographic film slides to a range of about 300 m. Hence, 200 mm lenses were used that yielded a field of view of 15° by 10°. To determine the positions for the targets a 35 mm camera with the 200 mm lens attached was used for viewing each of the two sites. The camera's line of sight was positioned with a conspicuous feature in the center of the field of view. A total of 24 target locations were identified for each of the two sites that represented easy to difficult targets for detection. These locations were referenced to several prominent scene features that were ranged with a binocular range finder.

Since there were only five people available for these tests, four were used as targets and one for positioning the targets and taking the photos. Hence, the targets had to be positioned in six different locations with the overall target positions ranging from about 110 m to 660 m for the first site and 400 m to 900 m for the second site. Hand-held radios were used to direct the camouflaged human targets into the correct positions. The cameras were placed on tripod mounts in a straight line that was perpendicular to the line of sight to the middle of the target scene field of view about 1.5 m above the ground. When the four targets were in their first position, the lines of sight from each of the stereo cameras to each target had to be checked to insure that the line of sight was not blocked. Then the targets held up large white cards to designate their position and one photographic slide was taken as quickly as possible from each of the stereo cameras. The targets were then instructed to turn around and hide their card and take either standing or crouching positions. By facing away the targets do not expose face or hand features that are strong detection cues for visible images. Two slide photos were taken of these targeted scenes from each of the stereo cameras. Then the targets were instructed to hide, and two slide photos were taken of these non-targeted scenes. This process was repeated six times to get the 24 target positions. The target scene for the first site without targets is shown in Figure 1. A composite target scene for the first site with all 24 targets with their white signs is shown in Figure 2.

3.2 Photo Processing

The collection of the photographic slide images for the first site took one day with sunny to partly cloudy conditions. The collection of the photographic slide images for the second site was accomplished on the next day with cloudy to rainy conditions. All of the film was then developed and digitized to 3,072 by 2,048 pixel resolution. Because of the significant changes of visibility with the rainy conditions present in the second day's testing, the first day was used for the initial analysis.

The imagery collected at the first site was collected with four different cameras. Of the four camera positions the photos from the right and left cameras were closest in terms of color matching. The center left was a little lighter, and the center-right was much lighter and more yellow even though all the cameras were set to the same exposure and aperture settings. There must have been a significant difference in the optics of the 200-mm lenses used. The color differences caused a significant slow down in the processing of the stereo pair images with Photoshop. To begin processing the right line of sight was used as the reference. A composite picture of all of the target locations (Fig. 2) was produced by splicing all of the target photos with white location cards displayed onto the photo with the first four target positions. A display grid was placed onto this composite photo to determine an optimum size for the initial display field of view size (the trick here was not to cut targets into pieces with the edges of the individual rectangular sectors). An array of four rows of seven sectors each allows a random distribution of unshared targets into the 28 sectors. Each sector was 396 pixels wide and 264 pixel high. With the 200 mm camera lens used each sector represents a 1.9° by 1.3° field of view.

The labeling of the sectors was alphabetically for the rows, A through D (top to bottom), and numerically for the columns, 1 through 7 (left to right). The sector B4 has a bush in the center that was the conspicuous feature in the center of the camera's field of view. The non-targeted and targeted B4 sectors are shown in Figs. 3 and 4, respectively. In order to produce the targeted image in Fig. 4, portions of two different targeted images were spliced together because there were one or more of the four targets in each targeted image present in the particular sector. This type of splicing had to be performed only for a few cases. For reference purposes, the D sectors had images with terrain ranges from about 130 m to 180 m; the C sectors, from 180 m to 340 m; the B sectors, from 340 m to 520 m, and the A sectors, from 520 m to 675 m. The A sectors have truncation of the range because of the basically vertical wall produced by the tree line beyond the road at about 625 m. Also, the A sector scenes on the right have a tree line at 340 m as the lower portion of the image.

The set of right line of sight targeted sectors had 15 sectors with one target, three sectors with two targets, one sector with three targets, and nine sectors with no targets.

3.2 Image Display

In order to present the images to observers the only means available was a computer monitor display. Photoshop was used to produce sets of targeted and non-targeted sector bmp files of 792 by 528 pixels or 1.2Mbytes for the RGB color image from the original 396 by 264 pixel images. There were 56 total images for the right line of sight. In order to obtain the correct stereo image for the other lines of sight, the center terrain feature of the right line of sight was found in the other lines of sight whole scene images and a 396 by 264 rectangular image sector was cut out around this center feature. As the angular separation increased there were a few sectors that could not be matched. A random ordering of the targeted and non-targeted sectors was performed such that the ranges were mixed and targeted and non-targeted images were mixed with the additional constraint that the same sector targeted and non-targeted scenes were separated by several intervening different sector images. Finally, because of the limited number of sectors a targeted sector with an easily detected target, A4, was shown first as a learning image. Power Point was used to produce four separate slide shows of 128 scenes. The targeted and non-targeted scenes were separated by a black numbered scene with the first scene in the slide show as a black numbered scene. At present, an observer database has only been collected on the right line of sight imagery as viewed with both eyes looking at a single monitor.

4. DATABASE

4.1 Search and Target Acquisition Task

Some of the most useful search and target acquisition information can be obtained using eye tracking of the observer. Unfortunately, this type of analysis tool was not available. Hence, search time was picked as the quantifying parameter for the task of locating targets within the displayed scene. The observers were seated 1m from a computer monitor and briefed on the search and target acquisition task to be performed. The room was then darkened, and the observers were asked questions for about three minutes to allow them to become adjusted to the light level. The observers were then shown the slide show of targeted and non-targeted scenes as 20 cm wide by 13 cm high images with black borders. A stopwatch was used to measure the viewing time. The times and notes related to the location of targets or false targets found were recorded after each terrain scene was replaced with the black numbered scenes.

The observers were told that this is a search test focusing on how search times are influenced by scene content. What is desired from the observers is a concentrated effort to locate camouflaged personnel in a variety of backgrounds as quickly, yet as accurately, as possible. With this as a goal, the following are guidelines to the observer search task. (1) The targets are personnel with forest camouflage suits. (2) The personnel are either standing or crouched on the ground. (3) The targets are not perched in trees or minimally exposed with, for example, only an arm showing. (4) The personnel do not expose obvious high contrast features such as a face or hands. (5) The scenes vary dramatically in terms of range and background feature content. (6) In each scene there may be NONE, ONE, or MORE THAN ONE camouflaged personnel targets. (7) The target scenes will be alternated with black numbered scenes. (8) When a scene is shown, the task is to locate all the camouflaged personnel targets in the scene as quickly as possible. (9) Once all the targets are located the observer is to say "STOP," and the scene will be changed to the non-target display. (10) In cases where there could be confusion the observer will be asked to point out where in the scene they saw a target or targets to determine where the target was seen. (11) As scoring criteria, the observer will be given one point for each correctly identified target, minus one point for each false target identified, and minus two points for each target missed. (12) When the observer is ready for the next scene, they are to say "READY." (13) The observer will maintain a 1-m viewing distance from the monitor display. (14) For the sake of comparison, a typical fast response time for searching a scene is one to two seconds. (15) A typical slow response time for searching a scene is around 15 seconds.

To check on whether a target or false target was identified, the observers were asked to identify where they saw the target or targets in a three by three grid within the scene. The locations are top left, top center, top right, left center, center, right center, bottom left, bottom center, and bottom right. A sample of 30 observers was used with widely varying backgrounds.

4.2 Search times and target identifications

The observer testing resulted in a 56 by 30 array of detection times and a 56 by 30 by 9 (sector sub elements) array of target or false target detection locations. The detection location data shown in Table 1 will be considered first. Table 1 gives the targets (positive identification, PI in bold numbers) and false targets (false target, FT in standard numbers) as distributed within the sector sub elements. The NULL values represent the number of sectors for which no targets or false targets were found. With a sample size of 30 observers, a difficulty factor (D) was assigned as zero for a NULL value of zero no-detections, one for one to three, and one more for every three thereafter. Hence for the 28 to 30 no-detection level the difficulty was ten or D10. The difficulty factor was also applied to the PI values. In this case if there were a PI of 30 target detections the difficulty factor (D) of zero was applied. Here for every three less in the value of PI the difficulty was increased by one. Hence, for a PI of zero to two the difficulty was ten or D10. In the targeted sector A1 the NULL value was 12 and the target in the bottom center element also had a PI value of 12. Hence the scene had a difficulty of D4 whereas the target had a positive detection difficulty of D6. It was easier to find a target in this scene because another sector element (center) had a false target with an effective PI of difficulty D6. For the case of the untargeted sector A1 the NULL value of 16 represents a difficulty for finding a target or false target of D6 comparable to the false target.

The average search time in seconds for each sector will now be addressed with respect to the NULL difficulty for both non-targeted and targeted sectors. These results are shown in Table 2. The times given represent times taken for targeted and non-targeted sectors. For the cases where there was no target present, the same sector was shown twice (9 sectors). In these cases the times for the two cases were averaged and listed in the non-target sector times.

5. RESULTS

In general the times for the non-target sectors are longer than the target sectors. In fact there are only two cases where the target sectors (A1 and B5) have longer times than the overall average search time of 6.25 seconds. This makes sense though because these were the most difficult sectors to find the targets in with difficulties of D4 and D5 respectively. If the difficulties of D0 to D3 are considered low; D4 to D7, medium; and D8 to D10, high. The average search time for the non-targeted sectors with medium difficulty is 6.7 s and for high difficulty 7.5 s. For the targeted sectors with medium difficulty the time is 7.5 s and for low difficulty only 4.0 s. In essence if a target real or false is easy to detect, the search time drops significantly.

The range of average search times for individual observers was from 1.75 s to 13.88 s. There was a correlation between poor overall scores and longer search times. This is presented in Table 3. To better compare the results of the different observers with respect to the differences between times taken to search individual sectors, the times for each observer were normalized by dividing each time by their individual average search time. When this was done there were 852 sectors where no target or false target was detected taking an average normalized time of 1.15. There were 828 sectors where targets or false targets were found taking an average normalized time of 0.81. To better see how much time is taken to find a target or false target, the average normalized detection and no-detection times for each sector are compared versus the NULL difficulty in Table 4. Column 2 in Table 4 gives the normalized times to detect a target or false target. As the scene becomes more difficult (i.e., the NULL value increases, and there are fewer of the 30 observers who detect targets or false targets) the normalized time taken becomes longer. Also, in general it takes longer to determine that there is no target or false target present than when there is. When the false targets present are very target-like as in the case of most of the D4 and D5 samples, the detection time, TG-TIME, is short and the non-detection time, ND-TIME, is long. In addition, the number of false targets versus real targets detected increases as the NULL value increases. This is similar to over training a neural net.

There were a few examples of how moderate to difficult targets are missed in scenes when there is an easier target or false target detected first. The sector B4 had three targets present with PI difficulties of D10, D6, and D1 located, respectively, in the left center, right center, and center of the sector. This image gave a good example of how the human detection process works. When a search and target acquisition task is given, a fuzzy notion of what the target of interest is is formulated. The presented scenes are searched for this fuzzy target. If a detection of a real or false target is made, the target construct becomes well defined and the scene search is rapidly completed thereafter even if multiple targets are present and detected. This refinement in the target sought can cause targets to be missed. In sector B4 there is a fairly easy target to detect right in the middle. This is a standing target. The crouching target to the left and away from the tree line was only detected if it was seen first. Only two of the 30 observers accomplished this. Both of these observers were able to then detect the center easy target but did not detect the moderately difficult target on the right center. A similar occurrence happened in sector A1 where there was a bush that very much resembled a standing target in the center of the sector. This made the detection of the crouching real target in the bottom center more difficult.

6. STEREO VISION

The initial viewing of the stereo slide shows revealed some distinct problems. The images in the closest sectors (C and D) could not be fused for the field of view of the entire sector. There simply was too much parallax. At 110 m the approximate 1.9 m high human targets represent about 90% of the sector image height or 238 pixels. At 650 m the human targets represent only about 15% of the sector image height or 40 pixels. With a 6 m platform separation between the right and right-center cameras the resulting shift between the bottom and top elements of the scenes in the D sector is 1.8 m or 225 pixels with the standing target experiencing 90% of this shift from bottom to top. In the C sector the parallax shift bottom to top is 5.0 m or 180 pixels. This time a 1.9 m target in the bottom of the scene would represent only 45% of the height with only about 81-pixel parallax shift from the bottom to top of the target. Stereo fusion at this range was possible but not comfortable. Finally, in the B sector the parallax shift bottom to top is 6.3 m or 145 pixels. Now, the 1.9 m target in the bottom of the scene represents just 25% of the height with only about 36 pixel parallax shift from the bottom to top of the target. These images could be easily fused and showed good depth perception.
Hence, to be able to compare the results of single line of sight to stereo vision for the near targets would require a display of field of view about one third the one that was used for the closest sectors.

7. CONCLUSIONS

A search and target acquisition test was conducted that provided single and wide baseline stereo imagery for observer testing. The database contains the same scene with and without camouflaged human targets present. The analysis of imagery from the first of two sites has resulted in several interesting findings. First, a simple search task showed that search times are significantly longer for scenes where no target or false target is detected. Second, there was little difference in total search time for one or many detected targets. Third, as the normalized time that a scene is viewed increases the probability of false target detection also increases. Finally, the use of stereo vision for reducing the clutter level in search and target acquisition tasks has promise, but requires care in assessing. It cannot be done for short range targets without using multiple fields of view.

8. ACKNOWLEDGEMENTS

The authors would like to thank Dr. Matthew Valeton and the rest of the Vision and Imaging research team of the TNO Human Factors Research Institute, Soesterberg, The Netherlands. Without their assistance in assembling the equipment, in processing the photographic slides, and in providing the targets and test range needed for this experiment, this research could not have been possible. The human target especially will remember tromping through heather while getting soaked by rain and trying to guess how to respond to unintelligible hand-held radio messages.

9. REFERENCES

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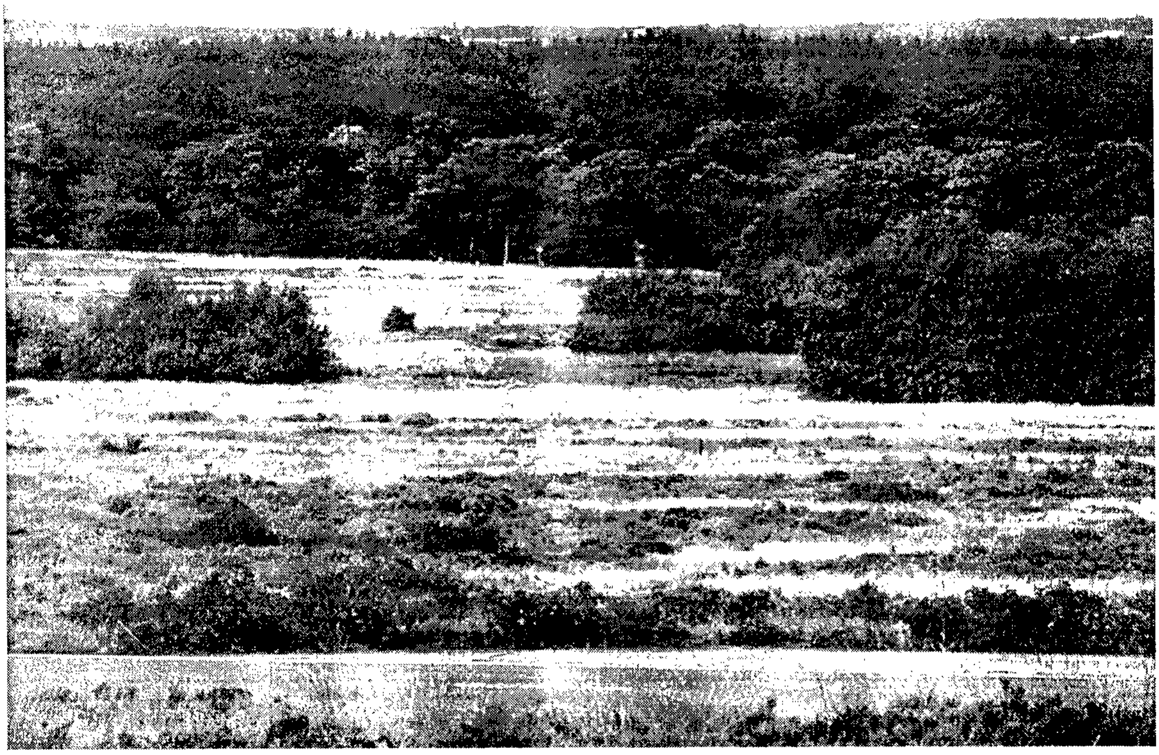

FIGURE 1. Whole scene with no targets.

FIGURE 2. Whole scene with target positions designated with large white cards.

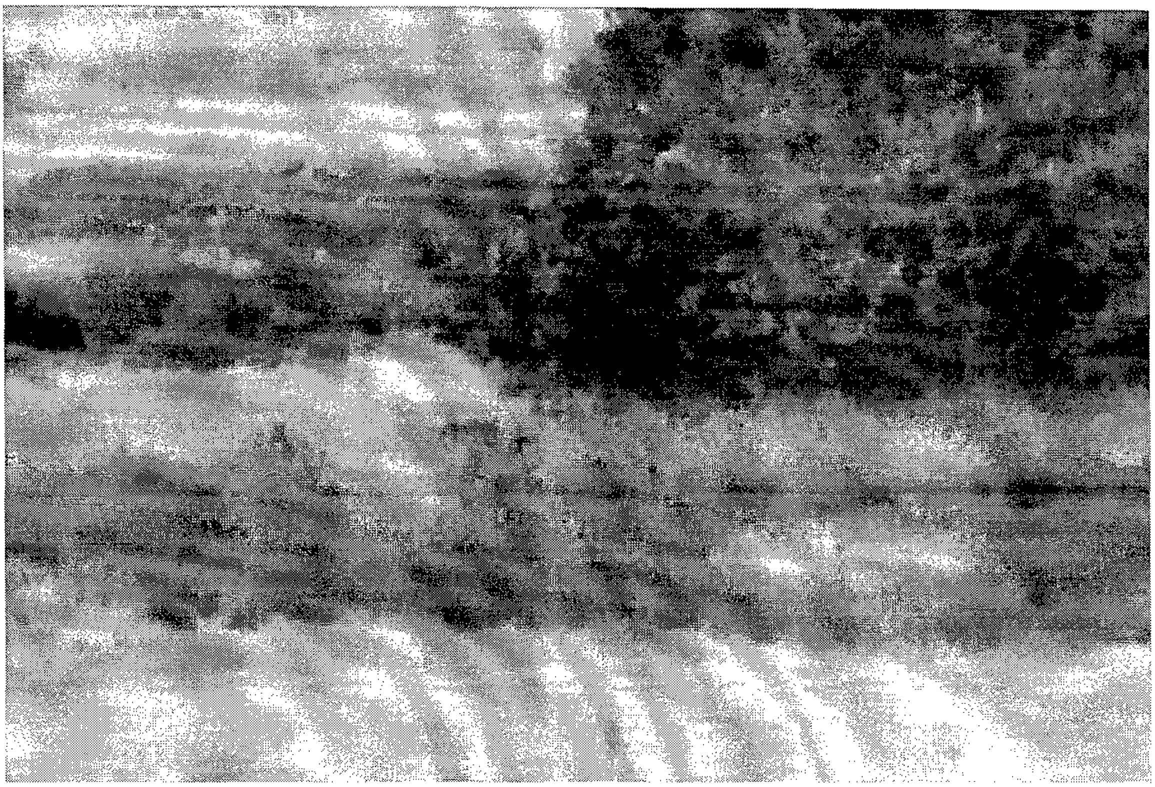

FIGURE 3. Non-targeted sector B4.

FIGURE 4. Targeted sector B4.

TABLE 1. SECTOR LOCATIONS OF TARGET AND FALSE TARGET DETECTIONS

A1	PI 12	0	0	0	A1	PI 0	0	0	0
TG (1)	FT 16	0	11	3	BK	FT 20	4	12	2
#22	NULL 12	1	**12**	1	#6	NULL 16	1	0	1
A2	PI 28	0	0	0	A2	PI 0	1	0	0
TG (1)	FT 3	**28**	3	0	BK	FT 10	4	3	2
#53	NULL 2	0	0	0	#38	NULL 24	0	0	0
A3	PI 0	0	0	0	A3	PI 0	0	0	0
TG (0)	FT 19	0	12	7	BK	FT 12	0	7	5
#28	NULL 20	0	0	0	#15	NULL 24	0	0	0
A4	PI 30	0	0	0	A4	PI 0	0	0	0
TG (1)	FT 3	3	**30**	0	BK	FT 13	10	1	1
#1	NULL 0	0	0	0	#48	NULL 17	1	0	0
A5	PI 0	0	0	0	A5	PI 0	0	0	0
TG (0)	FT 4	2	0	1	BK	FT 7	4	1	0
#43	NULL 27	0	1	0	#18	NULL 24	1	1	0
A6	PI 0	0	0	0	A6	PI 0	0	0	0
TG (0)	FT 39	34	5	0	BK	FT 40	38	2	0
#16	NULL 12	0	0	0	#50	NULL 10	0	0	0
A7	PI 0	0	0	1	A7	PI 0	0	3	1
TG (0)	FT 3	0	1	1	BK	FT 6	0	2	0
#47	NULL 28	0	0	0	#27	NULL 25	0	0	0
B1	PI 30	0	0	0	B1	PI 0	0	0	1
TG (1)	FT 2	**30** + 2	0	0	BK	FT 6	1	3	0
#41	NULL 0	0	0	0	#26	NULL 25	0	1	0
B2	PI 27	0	0	0	B2	PI 0	0	0	0
TG (1)	FT 2	**27**	1	1	BK	FT 7	1	2	4
#23	NULL 3	0	0	0	#3	NULL 23	0	0	0
B3	PI 30,23	0	**23**	0	B3	PI 0	0	0	1
TG (2)	FT 0	**30**	0	0	BK	FT 3	0	1	1
#55	NULL 0	0	0	0	#36	NULL 27	0	0	0
B4	PI 2,29,14	0	0	0	B4	PI 0	0	0	0
TG (3)	FT 0	**2**	**29**	**14**	BK	FT 4	2	2	0
#29	NULL 0	0	0	0	#14	NULL 27	0	0	0
B5	PI 12	0	0	0	B5	PI 0	0	0	0
TG (1)	FT 6	4	1	0	BK	FT 1	0	1	0
#4	NULL 15	0	**12**	1	#45	NULL 29	0	0	0

TABLE 1
CONT.

B6	PI 30,30	0	0	0	B6	PI 0	1	0	0
TG (2)	FT 1	0	0	0	BK	FT 8	0	1	0
#35	NULL 0	0	**30+1**	**30**	#24	NULL 25	0	4	2
B7	PI 30	0	0	0	B7	PI 0	0	0	2
TG (1)	FT 4	2	0	0	BK	FT 17	3	0	2
#10	NULL 0	1	**30**	1	#56	NULL 17	7	1	2
C1	PI 30	0	0	0	C1	PI 0	0	0	0
TG (1)	FT 6	2	4	**30**	BK	FT 11	5	3	0
#11	NULL 0	0	0	0	#54	NULL 25	0	2	1
C2	PI 30	0	0	0	C2	PI 0	0	0	8
TG (1)	FT 2	0	**30**	0	BK	FT 15	1	0	0
#43	NULL 0	1	1	0	#32	NULL 20	5	0	1
C3	PI 0	2	2	2	C3	PI 0	2	0	7
TG (0)	FT 7	0	0	0	BK	FT 12	0	1	2
#17	NULL 25	1	0	0	#2	NULL 20	0	0	0
C4	PI 29	0	**29**	1	C4	PI 0	3	0	1
TG (1)	FT 2	0	0	0	BK	FT 9	0	1	0
#49	NULL 1	0	0	1	#33	NULL 24	3	0	1
C5	PI 0	3	5	3	C5	PI 0	0	4	0
TG (0)	FT 19	1	0	4	BK	FT 14	1	2	5
#31	NULL 17	0	0	3	#12	NULL 20	0	0	2
C6	PI 30,28	2	0	0	C6	PI 0	5	1	2
TG (2)	FT 9	**30 + 5**	1	1	BK	FT 17	2	1	4
#5	NULL 0	**28**	0	0	#44	NULL 20	1	0	1
C7	PI 0	0	0	1	C7	PI 0	0	0	0
TG (0)	FT 10	1	4	0	BK	FT 10	1	3	3
#37	NULL 24	2	1	1	#21	NULL 24	1	0	2
D1	PI 30	0	1	0	D1	PI 0	1	0	2
TG (1)	FT 2	0	1	0	BK	FT 6	0	1	0
#40	NULL 0	0	**30**	0	#20	NULL 25	0	1	1
D2	PI 30	0	0	**30**	D2	PI 0	0	0	0
TG (1)	FT 4	0	1	0	BK	FT 17	2	2	0
#13	NULL 0	2	0	1	#51	NULL 18	6	0	7
D3	PI 30	0	1	0	D3	PI 0	1	0	2
TG (1)	FT 8	1	3	2	BK	FT 17	3	1	5
#46	NULL 0	1	0	**30**	#30	NULL 19	5	0	0

TABLE 1
CONT.

D4	**PI 0**	2	1	0
TG (0)	**FT 9**	1	0	0
#19	**NULL 22**	1	4	0
D5	**PI 30**	1	0	0
TG (1)	**FT 7**	0	2	0
#52	**NULL 0**	0	**30**	4
D6	**PI 30**	1	0	0
TG (1)	**FT 4**	1	1	1
#25	**NULL 0**	0	**30**	0
D7	**PI 0**	0	0	1
TG (0)	**FT 12**	1	6	1
#7	**NULL 20**	3	0	0

D4	**PI 0**	1	3	1
BK	**FT 12**	2	1	1
#8	**NULL 24**	0	2	1
D5	**PI 0**	2	0	0
BK	**FT 11**	0	3	3
#39	**NULL 24**	0	1	2
D6	**PI 0**	4	0	2
BK	**FT 18**	0	6	0
#9	**NULL 21**	1	4	1
D7	**PI 0**	0	0	0
BK	**FT 5**	1	4	0
#42	**NULL 26**	0	0	0

TABLE 2. SEARCH TIMES FOR TARGETED AND NON-TARGETED SECTORS

		1	**2**	**3**	**4**	**5**	**6**	**7**
A	no target	7.2 / D6	8.7 / D8	7.9 / D8	7.5 / D6	9.7 / D9	6.1 / D4	6.4 / D9
	target	**7.4 / D4**	**5.2 / D1**	**NT**	**3.7 / D0**	**NT**	**NT**	**NT**
B	no target	6.2 / D9	6.9 / D8	7.6 / D9	6.5 / D9	7.7 / D10	8.7 / D9	6.2 / D6
	target	**3.7 / D0**	**4.3 / D1**	**4.0 / D0**	**4.6 / D1**	**7.5 / D5**	**3.4 / D0**	**3.8 / D0**
C	no target	5.6 / D9	6.7 / D7	6.5 / D8	7.4 / D8	5.9 / D7	6.4 / D7	7.7 / D8
	target	**3.1 / D0**	**3.4 / D0**	**NT**	**3.3 / D1**	**NT**	**4.5 / D0**	**NT**
D	no target	7.4 / D8	6.9 / D6	7.4 / D7	8.1 / D8	8.6 / D8	8.0 / D7	7.2 / D8
	target	**3.9 / D0**	**4.6 / D0**	**4.1 / D0**	**NT**	**3.5 / D0**	**4.1 / D0**	**NT**

TABLE 3. OBSERVER SCORES AND TIME RANKING

PERSON	SCORE	TIME(s)	T-RANK	5R-AVG
1	18	3.88	8	----
2	17	2.16	2	
3	17	7.63	21	14.4
4	17	11.96	29	
5	16	4.35	12	----
6	15	13.88	30	----
7	14	3.32	4	
8	14	3.51	5	11.6
9	13	5.96	17	
10	10	2.59	3	----
11	10	1.75	1	----
12	9	3.73	7	
13	8	4.78	14	10.2
14	8	4.29	11	
15	7	7.71	23	----
16	7	4.17	10	----
17	7	6.76	18	
18	3	4.85	15	14.2
19	3	4.57	13	
20	2	4.08	9	----
21	-1	7.75	24	----
22	-7	5.68	16	
23	-12	9.6	25	19
24	-14	3.63	6	
25	-14	7.56	20	----
26	-14	6.98	19	----
27	-16	11.98	28	
28	-25	9.69	26	23.6
29	-26	11.04	27	
30	-95	7.71	22	----

TABLE 4. NORMALIZED TIMES AS A FUNCTION OF TARGET DIFFICULTY

D	TD-TIME	#	ND-TIME	#
0	0.64	13	-----	0
1	0.74	4	0.8	4
2	-----	0	-----	0
3	-----	0	-----	0
4	0.9	3	1.29	3
5	1.1	1	1.48	1
6	1.05	5	1.13	5
7	1.07	8	1.19	8
8	1.34	10	1.24	10
9	1.12	10	1.08	10
10	0.96	2	1.11	2